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# A Potential Source of Energy

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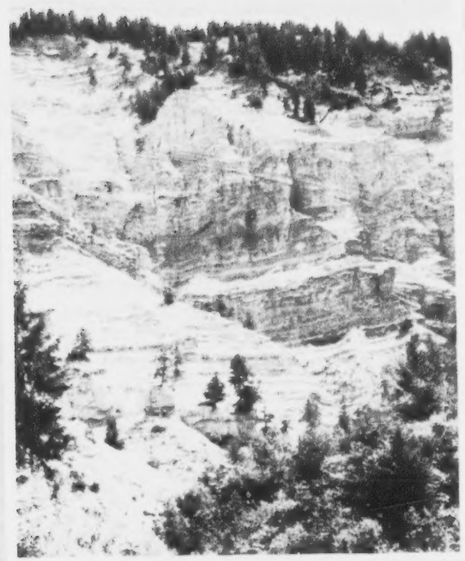

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U.S. Department of the Interior/Geological Survey

# Oil Shale:
# A Potential Source of Energy

by Donald C. Duncan

Oil shale is a potential source of energy, and a valuable one now as the Nation's supplies of conventional fuels dwindle and become more costly.

Just what is oil shale? Oil shale is a very fine-grained sedimentary rock containing enough organic matter (hydrocarbon) to yield varied amounts of oil per ton when processed.

The U.S. Geological Survey is studying the organic material and the chemical and physical environments to learn more about the natural processes that produced oil shale.

This publication is one of a series that explores the ecosystem of the Green River Formation in Colorado, Utah, and Wyoming.

Extracting oil from solid rock might seem to be as fanciful as squeezing blood from a turnip, but a tremendous amount of virtually untapped oil is locked in rock called *oil shale*. In the United States alone shale oil resources probably exceed 2,000 billion barrels of petroleum (42 U.S. gallons per barrel). Scientists and engineers have developed and successfully tested shale oil extraction processes for large-scale pilot operations.

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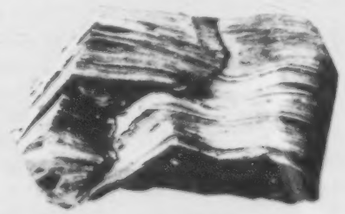
## What Is Oil Shale?

Many organic-rich shales yield oil, but because of this low-grade yield (1 to 10 gallons per ton), they are not called "Oil Shale." To earn the name, oil shale must yield a minimum of 10 gallons of oil per ton when properly processed. Some shales yield much more, however, and in the United States some thin layers have been reported to yield as much as 140 gallons per ton. Shales of commercial interest will yield from 25 to 65 gallons of oil per ton, though some foreign deposits yielding between 10 and 25 gallons per ton have been mined successfully on a large scale.

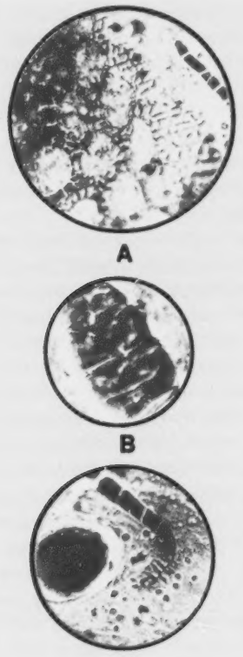
The combustible portion of oil shale is mostly solid organic matter composed of carbon, hydrogen, oxygen, and usually small amounts of nitrogen and sulphur. Some oil shales contain substantial amounts of bitumen (incombustible asphalt-like material) intimately mixed with solid organic matter. Other incombustible minerals such as calcite, dolomite, clay, quartz, and feldspar generally make up more than half the rock.

Most oil shale is dark (black, brown, or dark grey), but some layers are colored yellow, red, or green by waxy organic materials. By viewing very thin slices of these rocks through a microscope, one may see small mineral grains surrounded by dark shapeless masses of organic matter speckled with brilliant yellow, red, or green particles. These



An oil shale fragment.

particles are probably fossil remains of spores, pollen, or filaments of algae, a single-celled plant. The remains of other plants or animals may also be conspicuous, though the organic matter is generally so finely pulverized that the fossils cannot be recognized.




Microscopic views of oil shale thin sections: (A) shows fossil pollen and other plant tissue from oil shale. (B & C) Fossil algae filament cyst and spore *(photo by Estella Leopold).*

When shale is heated in a retort to a temperature of about 900 F, some of the organic material melts, and when this liquid is heated to higher temperatures, gases form. The vapors can be condensed to form oil, with part remaining as hydrocarbon gas. From 25 to 75 percent of the organic matter in oil shale can be converted to oil and combustible gas. The remaining carbon forms combustible char or coke.



## History

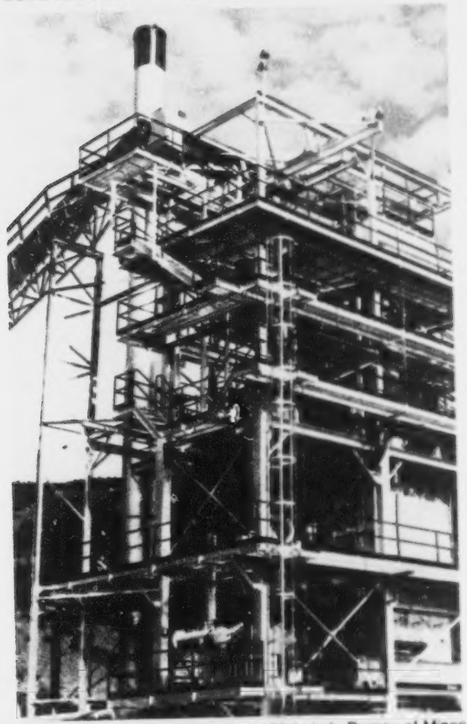
Oil shale was first used in Europe during the Middle Ages as a solid fuel for heating or cooking. As early as the 14th century, a dark sulphurous oil known as *ichthyol*—so named because the oil was released from shale containing fish remains—was obtained from deposits in Austria and Switzerland. This type of oil is still used as medicinal ointment. During the industrial revolution in Europe, the need for oil to supplement costly vegetable and animal oils led chemists and miners to search for more of the stone that yield oil when heated. By the mid-19th century, many small industries were processing oil shale. Forerunners of modern petroleum refining plants, they produced candle wax, kerosene, lubricants, and combustible gas.

A few small oil shale industries were developed in the United States during the 1850's. Deposits of shale in the Appalachian coal region and along the Ohio River Valley were mined to produce oil and illuminating gas, but these infant refineries were abandoned after the Drake well, drilled in 1859 at Titusville, Pa., showed that petroleum could

Engine house and derrick of oil well drilled by Edwin L. Drake in 1859 near Titusville, Pennsylvania.

be produced less expensively from underground reservoirs. Periods of research, development, and promotion of oil shale followed World Wars I and II when major increases in the use of oil foreshadowed possible shortages.

From 1944 until 1956, the Department of the Interior's Bureau of Mines conducted extensive research on the mining and retorting of oil shale and the refining of shale oil at the Anvil Points Experiment Station in Garfield County, Colo. The plant has been leased in recent years to private organizations for additional research. In laboratories at Laramie, Wyo., the Bureau continues research on advanced shale oil production methods.



Oil shale retort of the Department of Interior's Bureau of Mines Anvil Points Experiment Station, Naval Oil Shale Reserve, Garfield, Colorado.



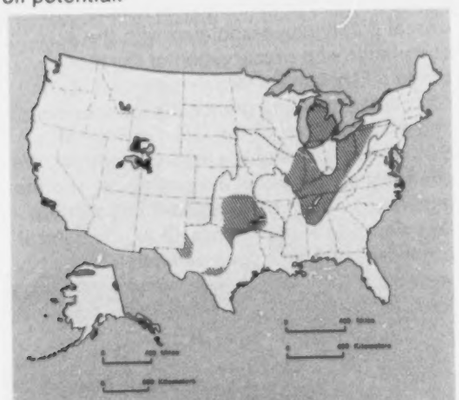
## How Was Oil Shale Formed?

Oil shale accumulated as layers of organic ooze and mud on the bottoms of ancient lakes, ponds, lagoons, and shallow seas—places where plant or animal life was abundant. As organisms died and sank to the bottom, their remains were partly preserved—particularly where the water was stagnant and lacked sufficient oxygen for complete decay of organic matter. The organic-rich layers of mud were gradually buried as younger sediments accumulated above them, and the weight of the overlying material slowly turned the mud into hard shale. The unsual conditions associated with the accumulation and preservation of the higher grade oil shales are largely unknown. Earth scientists, including geologists, geochemists, and geophysicists of the U.S. Geological Survey, are studying the organic material, the chemical and physical environments, and the mineral composition of ancient and modern lake deposits to learn more about the natural processes that produced oil shale.

Close-up view of rich oil shale exposed in a quarry near DeBeque, Colorado.

## Where Are Oil Shale Deposits Found?

Oil shale is widely distributed in sedimentary rocks throughout the world. It is present in some of the earliest known fossiliferous rocks (about 600 million years old) and also in many younger rocks, including a few small deposits that formed in modern lakes. There are deposits of organic-rich shale in the United States other than those shown on the map, but most of these have not been tested sufficiently to determine their oil potential.



**Explanation**

Tertiary deposits: Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California. Middle Tertiary deposits in Montana. Black areas are known high-grade deposits.

Devonian and Mississippian deposits. Boundary dashed where concealed or where location is uncertain.

Mesozoic deposits: Marine shale in Alaska.

Permian deposits: Phosphoria Formation, Montana.

Principal oil shale deposits of the United States

## Deposits in the Green River Formation

The most extensive high-grade deposits known in the United States are in the Rocky Mountain region underlying lands that are mostly in the public domain. They extend throughout an area of more than 3,000 square miles in parts of Colorado, Utah, and Wyoming. Within this region the oil shales are part of the sedimentary materials that accumulated in the bottoms of two vast shallow lakes that existed during the Eocene Epoch of the Tertiary Period (about 50 million years ago). These lake-basin sediments have been named the Green River Formation from exposures near the Green River in Wyoming. In many places the layers of oil shale are visible in cliffs and ledges along present-day stream channels. The extent, oil content, and thickness of the oil-bearing shale have been studied by the U.S. Geological Survey and the Bureau of Mines to appraise the oil potential of deposits in the public domain. From assays of drill samples obtained by private companies and Federal

Green River Formation exposed along Hells Hole Canyon, Unitah County, Utah (Mahogany Zone between arrows)



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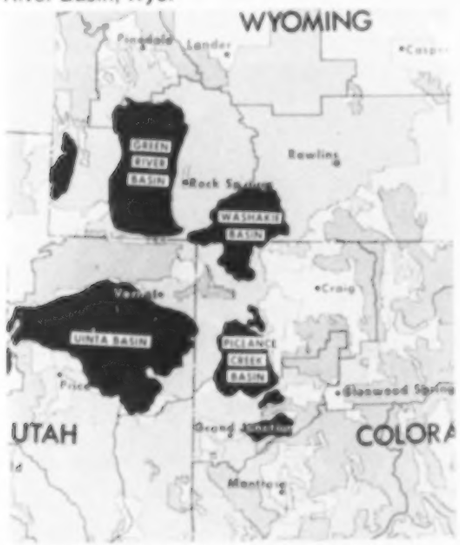
agencies, the Geological Survey has determined that the richest oil shale deposits are buried beneath younger sedimentary rocks near the central parts of the ancient lake basins.

The largest deposits of high-grade oil shale are in the Piceance Basin of northwestern Colorado. In the southern part of the basin a rich layer known as the Mahogany Zone, ranging from 50 to 100 feet in thickness, is exposed in cliffs north of the Colorado River. In the north-central part of the basin, about 1,000 feet of rich oil shale lies buried under 500 to 1,600 feet of sandstone and lean or barren shale. The oil shale (including low-grade shale) in the Piceance Basin alone had been estimated to contain 1.3 trillion barrels oil equivalent. Layers of oil shale are also exposed along the south and east margins of the Uinta Basin in Utah; they increase in thickness and improve in quality below the surface in the eastern half of the basin. Thick layers are deeply buried in the Green River Basin, Wyo.




Areas underlain by the oil-shale-bearing Green River Formation.



## Deposits in Central and Eastern United States

Black shale, some of which is oil-bearing, was deposited in ancient shallow seas and now lies buried throughout large areas of the Central and Eastern United States. The layers of oil shale in these deposits are generally thin (5 to 20 feet thick) and low grade (10 to 20 gallons of oil per ton). A substantial amount of the shale yields only 5 to 10 gallons of oil per ton, and is not classified as oil shale. The geographic distribution of one of the most extensive oil-bearing black shale sequences deposited during the Late Devonian and Early Mississippian Periods (about 350 million years ago) is shown on the map. To determine their oil yields, the deposits have been examined and tested in some detail along outcrops in parts of Indiana, Kentucky, and Tennessee, but they have been tested less thoroughly in Ohio, Michigan, Illinois, Missouri, Kansas, Oklahoma, and Texas. Incompletely explored parts of the deposits contain about 200 billion barrels oil equivalent, and parts that are less well known may contain an additional 800 billion barrels in shale yielding 10 gallons or more per ton.

Oil-bearing black shale in DeKalb County, Tennessee *(photo by Louis C. Conant)*.

## Deposits in Other Areas

Large deposits of oil shale that formed during the Jurassic and Cretaceous Periods (70 to 180 million years ago) occur near the Brooks Range in northern Alaska, and deposits of the Triassic Age (180 to 225 million years ago) occur in eastern Alaska. Although the deposits have been studied in detail at only a few places, their oil potential is believed to be large.

Oil-bearing shales composed largely of the remains of diatoms (a one-celled water plant) that accumulated during the Miocene Epoch of the Tertiary Period (11 to 25 million years ago) are widespread in southern California. Both high-grade and low-grade shales are present, and they reportedly contain about 70 billion barrels oil equivalent. They also contain soluble bitumen and insoluble organic matter. Mining on a small experimental scale has produced oil plus lightweight aggregate for construction material.

Layers of chert and shale (arrow), Kiligwa River, Brooks Range, Alaska *(photo by Irving Tailleur)*.



Extensive marine deposits in southwestern Montana contain low-grade black shale yielding 10 to 20 gallons of oil per ton. Other deposits that formed in ancient lake basins of western Montana contain high-grade oil shale, and, although they have not been appraised in detail, some are large.

Cliffs of oil shale north of the Colorado River, Garfield County, Colorado.

## Products and Uses

Oil shale can be burned as a solid fuel or it can be processed to yield oil or combustible gas in varying amounts according to the extraction methods used. The principal item of commercial interest generally has been oil, but other products can be obtained. Combustible hydrocarbon gas, for example, has been a major product of some European shale industries. Sulphur and nitrogen

compounds, undesirable in combustible fuels such as oil and hydrocarbon gas, can be recovered separately as valuable by-products. The inorganic fraction of some oil shales also contains materials such as sodium carbonate and phosphate minerals, and aluminum, uranium, vanadium, copper, or molybdenum in extractable concentrations. After the oil is removed, the spent shale can be used for lightweight aggregate.

## Potential Resources

The oil shale deposits of the United States can be considered collectively as an enormous low-grade source of oil, hydrocarbon gas, or solid fuel. Deposits with an estimated yield of 10 gallons or more oil per ton of rock contain more than 2 trillion barrels; their possible extensions may contain an additional 3 trillion barrels; and, speculatively, other unappraised deposits may contain several times as much oil.

At present, only the highest grade and more accessible oil shales are of commercial interest. Such potential resources are more than double the proven reserves of petroleum in the country. However, using demonstrated methods of extraction, recovery of about 80 billion barrels of oil from accessible high-grade deposits of the Green River Formation is possible at costs competitive with petroleum of comparable quality. Experiments to extract oil or gas by heating the shale in place have been made on some deposits. If an experimental method for extracting oil from shale should prove to be economical on an industrial scale, the supply of oil from shale will be enormous.

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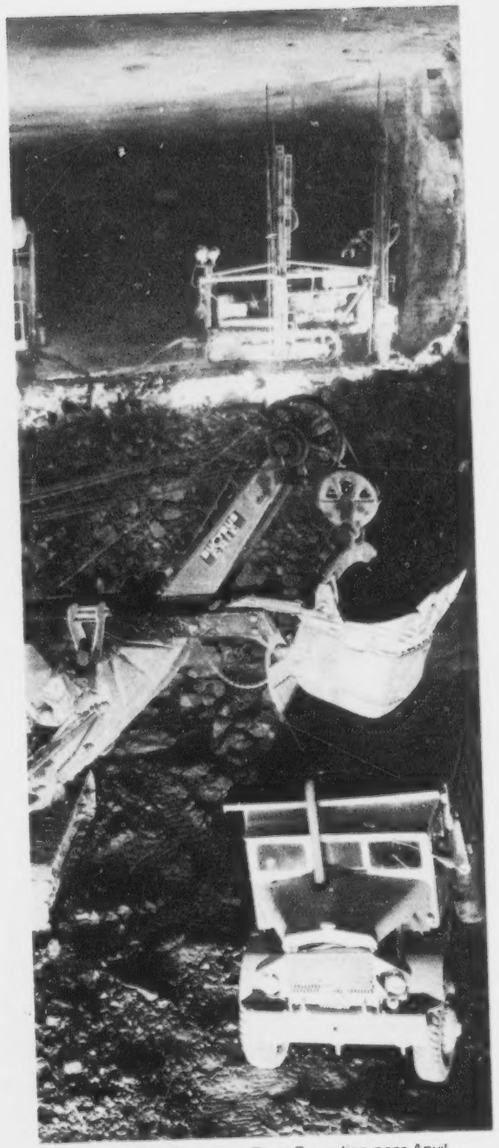

Oil shale mine in the Green River Formation near Anvil Points, Garfield County, Colorado

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